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BOX PATENT APPLICATION
WASHINGTON, D.C. 20231

jc586 U.S. PTO



06/08/99

CASE DOCKET NO. YO999-190

Date: June 8, 1999

EXPRESS MAIL LABEL NO.: EL295373155US

DATE OF DEPOSIT: JUNE 8, 1999

jc526 U.S. PTO
09/32708



06/08/99

Sir:

Transmitted herewith for filing under rule 1.53(f) is the Patent Application of:

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For: REPRESENTING, CONFIGURING, ADMINISTERING, MONITORING, AND/OR MODELING
CONNECTIONS USING CATALOGS AND MATRIXES

Enclosed are:

☒ 13 Sheets of formal Drawings.

☐ An assignment of the invention to International Business Machines Corporation, Armonk, New York 10504.

☐ A certified copy of a _____ application.

☒ Declaration and Power of Attorney is attached to the application.
(UNSIGNED)

☐ Associate Power of Attorney.

☐ Information Disclosure Statement with form PTO-1449 with references attached.

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IBM



09-0468

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1 REPRESENTING, CONFIGURING, ADMINISTERING,
2 MONITORING, AND/OR MODELING CONNECTIONS USING
3 CATALOGS AND MATRICES

4 CROSS REFERENCE

5 This invention application is cross referenced with
6 Docket Number YO999-272, entitled, "DISPLAYING,
7 ORGANIZING AND EMPLOYING EMBEDDED INFORMATION," by
8 Louis Herzberg et al., even-dated herewith, and is
9 incorporated herein by reference in entirety.

10 FIELD OF THE INVENTION

11 This invention relates to the field of network
12 connection. More particularly, the invention relates to
13 user interface and representation of connectivity.

14 BACKGROUND OF INVENTION

15 This invention addresses the problem of intuitively
16 representing and managing large data stores of
17 information relating to network configuration,
18 connectivity, resource utilization, connection
19 management and service availability. Although this
20 problem is particularly relevant in computer
21 controlled communications networks, it is also
22 prevalent in other types of networks which require

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1 specified interconnectivity of a large multiplicity of
2 network elements. Network administrators lack intuitive
3 tools to retrieve and view status of network elements
4 organized in a number of different formats, such as by
5 user, by host, by connection type etc. The
6 administrators also need simple means of querying,
7 adding and deleting information from the store.

8 Broadly speaking, there are two general methods of
9 configuring, administering, monitoring modeling
10 networks: graphical and non-graphical. This invention
11 defines a method of using a non-graphical intuitive
12 method for organizing information using "catalogs" (or
13 lists), methods for creation and manipulation of
14 elements within catalogs, methods for presentation of
15 catalogs, manipulation of catalogs and linking of
16 tasks to catalog elements.

17 In networks with more than a few connections between
18 network elements, graphical methods that show
19 connections among network elements as visible lines
20 are hampered by the size of display area required to
21 show the connections in a useful way. This method is
22 also limited in the amount and type of information
23 about the connection and network elements that can be
24 shown. Practically, with more than a few 10s of
25 connections, the number of lines becomes so large that
26 a graphical display (either on screen or on paper)
27 becomes too cluttered to be useful. Figure 1 shows an
28 example of a network 100 having ten elements, 101-110,
29 which are mesh connected. No additional information
30 (such as type of link, link status, traffic load,

1 configuration options, etc.) beyond connectivity among
2 elements is shown in the figure. Even with only this
3 one piece of information, the graphical image is
4 beginning to become unusable. Thus a better method of
5 representing connections between network elements is
6 needed.

7 The following are definitions of terms as used herein:

8 Network Element - the start or end point of a
9 connection.

10 Sub-element - element that is a member of a
11 catalog that is itself an element in a catalog.

12 Catalog - a named set of elements. The catalog
13 elements can be atomic or can themselves be a
14 catalog, thus enabling catalogs of catalogs of
15 catalogs and so on.

16 Sub-catalog - A catalog included in another
17 catalog.

18 SUMMARY OF INVENTION:

19 It is therefore an aspect of the present invention to
20 present a method, apparatus and architecture for the
21 representation visualization, manipulation,
22 administration, monitoring and modeling of connections
23 between elements of a network.

1 The invention includes catalogs of elements and the
2 manipulation of elements and/or catalogs, matrix
3 display and/or representation of catalogs and
4 manipulation of the matrix.

5 Aspects of this invention include:

6 the ability to represent, in a practical method, a
7 large plurality of connections;

8 the ability to configure the connections;

9 the ability to abstract different level or views of
10 the network;

11 the ability to show information about the
12 connections organized on the basis of different
13 parameters;

14 the ability to monitor, execute problem
15 determination tasks and tune the connections; and

16 the ability to use the same information
17 model/connection representation as input to modeling
18 tools.

19 Another aspect of this invention is the ability to use
20 a common view of the network for configuration,
21 monitoring, problem determination, tuning, modeling,
22 etc.

1 These and other objects are provided in a connection
2 representation scheme wherein a connection matrix is
3 employed. Other objects and a better understanding of
4 the invention may be realized by referring to the
5 Detailed Description.

6 BRIEF DESCRIPTION OF THE DRAWINGS

7 These and other objects, features, and advantages of
8 the present invention will become apparent upon further
9 consideration of the following detailed description of
10 the invention when read in conjunction with the drawing
11 figures, in which:

12 Fig. 1 shows a graphical representation of 10 network
13 elements mesh connected;

14 Fig. 2 illustrates an example of a High-level flow of
15 method;

16 Fig. 3 shows a matrix with Catalog "123" versus Catalog
17 "ABC" with one connection identified;

18 Fig. 4 shows a matrix with multiple connections at the
19 same intersection identified;

20 Fig. 5 shows an expansion of a Catalog Element;

21 Fig. 6 shows an expansion of a Catalog Element that is
22 in itself a Catalog;

1 Fig. 7 shows an example of input/output block for a
2 connection identified by the intersection of catalog
3 elements;

4 Fig. 8 shows an example of steps for configuring a
5 network;

6 Fig. 9 shows an example of steps for changing a
7 connection;
8 Fig. 10 shows an example of a matrix of connections
9 showing possible monitoring method;

10 Fig. 11 shows an example of a matrix of connections
11 showing possible problem determination and tuning
12 method;

13 Fig. 12 shows an example of steps for modeling a
14 network; and

15 Fig. 13 shows an example of a matrix with catalogs with
16 one intersection identified.

17 DETAILED DESCRIPTION OF THE INVENTION

18 This invention provides methods, apparatus and computer
19 related articles for connection representation used for
20 configuration, administration, monitoring, modeling
21 etc. In a prime use of this invention the connections

are logical connections, often referred to as overlay networks. For example, it provides input/output modeling in a network-wide view of network elements for VPNs, QoS overlay networks, etc. This invention can also be used on other overlay networks such as VLANs. The connections are not required to be logical but can be physical as well; i.e., this invention can also be used in the context of non-overlay networks, e.g. for showing the physical connectivity between network elements.

An example embodiment of a method to implement the invention is shown in Figure 2. In 210, catalogs are formed. In 220, the matrix is created and displayed. In 230 a connection representation between pairs of elements in the catalog is formed. From this connection information, actions may be taken within the network to cause the network to instantiate the connections that are defined in 230. The network administrator uses the matrix created in 230 as a basis for monitoring 240, problem determination 250, tuning 260 and/or modeling 270, etc.

It is advantageous to form catalogs of elements considered for interconnection by themselves. Thus, each instance of an object class or type is in a list or catalog. There can be multiple catalogs of the same object class. For example, in the object class of routers, one catalog includes all routers on the west coast, and a separate catalog includes all routers in the east cost. Catalog elements are manipulated such that a new catalog is created from the intersection or

1 union of existing catalogs. Elements can be ordered,
2 added, moved and deleted from one or more catalogs.
3 Examples of object classes (the type of catalogs)
4 include one or more of the following:

- 5 • Endpoint catalog - which includes a set of
6 endpoint elements that can connect to other end
7 point elements.
- 8 • QoS catalog - which includes the types of (Quality
9 of Service) QoS that are available, e.g.
10 guaranteed latency, guaranteed bandwidth, best
11 effort, etc.
- 12 • Tunnel catalog - which includes the types of IPSec
13 tunnels that are available, e.g. weak tunnel,
14 normal secure tunnel, extremely secure tunnel,
15 etc.
- 16 • Encryption methods catalog - which includes the
17 types of encryption that are available, e.g. DES,
18 3DES, RC4, blowfish, etc.
- 19 • Validity catalog which includes the times that the
20 connection is valid, e.g., normal business hours,
21 not first shift, Saturdays 10 to 11 AM, etc.
- 22 • Action catalog - which includes the type of
23 actions that a user can do, e.g. halt traffic
24 between the endpoints, cause an IPSec key exchange
25 to occur immediately, update the monitoring
26 information, etc.
- 27 • Traffic Loading catalog - which includes the
28 network traffic characteristics (e.g. frame size
29 distribution, frame transmission distribution) for
30 use as loading input to a network model.

horizontal axis) in that single direction only. For example, in Figure 3, intersection (D,4), 330, has a connection directed from Endpoint D, 314, to Endpoint 4, 324, but not a connection directed from Endpoint 4 to Endpoint D.

If the intersection cell represents duplex connections, the intersection exists twice in the matrix as intersection (D,4) and intersection (4,D). In some embodiments the duplex intersection cells are shown as mirror images of each other. Sometimes the intersection cell connection in one direction is shown shaded gray, while the connection in the other direction is shown unshaded.

Multiple connections between the same endpoints are created within the intersection block by logically "stacking" the intersection blocks. For example, for each connection (either simplex and/or duplex) a block is created. Each block represents a particular logical connection. Thus, a matrix with three dimensional (3-D) towers is created. Three connections, 401-403, between the same endpoints are shown in the common intersecting cell 410 in Figure 4.

In a GUI implementation, multiple connections are advantageously shown by either a 3-D method, as illustrated in Figure 4, item 410, or by a graphic within the cell indicating that there are additional blocks "under" the currently visible block.

For simplicity in illustrating the concepts of the present invention, only one duplex connection is shown between endpoints in the figures that follow. However, those familiar with the art can easily implement the concepts using other beneficial implementations for single, duplex and/or multiple connections.

It is noted that the elements along a matrix axis can be members of more than one catalog, and/or more than one catalog can be displayed on each axis of the matrix. Generally, both catalogs of elements, and elements that are not in and of themselves catalogs may be displayed simultaneously on an axis. Additionally, it should be realized that the same catalog or set of catalogs or elements can be display on both axes. When this occurs and connectivity is assumed for all matrix intersections, a mesh connected network results.

A star connected network results when a catalog having multiple elements (or even other catalogs) is assigned to one axis, a single element is assigned to the other axis, and connectivity is assumed for all matrix intersection cells.

The matrix display of catalogs is extended beyond the concept of using the intersection of catalog elements, to the concept of using each catalog element itself. In the example that follows, the catalogs contain routers, or network elements, that proxy or act as a gateway for sets of network elements located "behind" the router.

1 Figure 5 shows a case which uses matrix, 300, when the
2 user selects ("clicks on") a catalog axis element, 510.
3 In this situation, information about the constitution
4 of the catalog element is displayed, 520.

5 This approach is extended to elements of a catalog that
6 are in and of themselves a catalog. In this situation
7 catalog/elements are embedded within other
8 catalog/elements. Figure 6, shows a case using matrix
9 300, wherein one selects element, 510, and obtains that
10 which constitutes this element, 520. Now, when one
11 selects ("clicks on") Subnet 10, in 520, a sub-catalog
12 630 is displayed. Sub-catalog 630 is a list of network
13 elements within Subnet 10. Now, when one selects
14 ("clicks on") one of the network elements of catalog
15 630, one is shown a sub-catalog, 640. In this case,
16 sub-catalog 640 is a list of applications executing on
17 that network element. Since, in general, network
18 elements are not limited to traditional network
19 equipment, but may also include hosts and clients,
20 representation of additional relevant information is
21 possible. For example, one could further select
22 (click-on) one of the applications and be shown a
23 catalog, 650, (a list) of users of that application.
24 Furthermore, one could select (click-on) a user and
25 view usage statistics about that user. This process can
26 continue to show more and more embedded information
27 regarding a connection.

28 Now we consider an example of an initial configuration.
29 It is noted that details of this step are generally
30 implementation dependent and may also vary with the

1 network type. Figure 7 shows a way to configure
2 connectivity between two endpoints. In this simplified
3 example, it is assumed that a user is trying to
4 configure an IPSec based VPN and must specify the type
5 of tunnel, the type of QoS and the user of the tunnel.
6 The network administrator displays the catalogs of
7 interest along the edges of the matrix, 300, and
8 selects (clicks on) an intersection of endpoints within
9 the matrix. This brings up, 710, which is a set of
10 catalogs or lists which offer the connectivity
11 attributes that can be or should be set or a wizard to
12 aid in the choices of appropriate values for the
13 attributes.

14 For illustration simplicity and clarity, the concept of
15 multiple connections between the same endpoints as
16 noted above is not shown in the following
17 illustrations.

18 In one embodiment, the steps for configuring are as
19 shown in Figure 8.

20 Step 1. Select Logical Connection by "clicking on"
21 or selecting an intersection point 810. This
22 brings up a "selection box" that contains fields
23 for the pertinent information.

24 [Thus, in the example of Figure 7, each
25 direction 711, 712, is configurable
26 separately so as to give meaning to the From,
27 715, and To, 716, fields. It is assumed that
28 the catalogs of tunnel types 713, QoS types

1 714, and potential tunnel users have been
2 previously populated. The question marks 720
3 indicate fields that when selected, a
4 "wizard" or catalog of possible values is
5 displayed. For example, a wizard is displayed
6 when the catalog of values is not complete or
7 to help in selecting the value from a
8 catalog.]

9 Step 2. For each field, select a value from a
10 catalog of possible values, 820.

11 Step 3. After selecting values for all fields, the
12 user has completed the configuration for the
13 connection between the two end points and the
14 configuration is stored for retrieval and/or
15 display as desired, 830.

16 It is noted that all examples are only representative
17 illustrations of the invention, and are not
18 comprehensive enumeration of the fields that must be
19 completed for configuration in a particular embodiment.

20 An embodiment for changing configuration is shown in
21 Figure 9. The same concept used for initial
22 configuration is used for modifying an existing
23 configuration. The steps are as follows:

24 Step 1. Given a connection exists between two end
25 points as shown by the intersection of an element
26 from two matrix displayed catalogs, the user

1 selects that connection from the matrix
2 intersection that represents the connection, 910.

3 Step 2. Given the matrix intersection connection
4 selection, the user changes the attributes of the
5 connection by "clicking-on" that selection, 920.
6 This brings up a selection block that contains
7 changeable information. For example, this may be
8 the same selection block that was used to
9 configure the connection. The user clicks on a
10 changeable field which results in the display of a
11 catalog whose elements could be used in the field,
12 or a wizard may become available to configure the
13 field.

14 Because the elements that form axis of the matrix can
15 be catalogs in and of themselves, a matrix
16 intersection cells can represent a catalog of
17 connections. This catalog of connections can operate in
18 a way similar to the way shown in Figure 6.
19 For example, assume a highest level catalog is named
20 *east coast*. It includes elements which are in and of
21 themselves catalogs, namely: *Miami, Atlanta, Durham,*
22 *and Hawthorn*. Each of these includes elements which are
23 in and of themselves catalogs. The *Miami* catalog has
24 included elements, namely: *router 1, router 2 router 3*.
25 Each of these included elements are catalogs that
26 contain other included elements. Thus, *router 1* catalog
27 contains elements *interface 1, subnet w.x.y.z, specific*
28 *IP address a.b.c.d. and so on*.

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1 The phenomenon of embedding intersections within other
2 intersections may continue as needed by the particular
3 application and network. Thus one could begin with a
4 1x1 matrix of *east coast* verses *east coast*, which only
5 has a single intersection cell. Selection of this
6 single intersection cell, generates an expanded
7 "submatrix" whose both axes contain cities, namely:
8 *Miami, Atlanta, Durham, Hawthorn*. Selecting the
9 intersection, *Miami* verses *Miami*, generates an expanded
10 submatrix whose axis contains a *list of routers*,
11 namely: *router 1, router 2, router 3*. Further,
12 selecting the intersection, *router 1* versus *router 1*,
13 generates an expanded submatrix whose axis contains
14 network components, namely: *interface 1, subnet*
15 *w.x.y.z, specific IP address a.b.c.d*. One could then
16 select any of these network component intersections,
17 say *interface 1* verse *subnet w.x.y.z*. This intersection
18 represents this particular connection of the many
19 possible within the network. This operation is herein
20 referred to as matrix expansion. Matrix expansion is
21 used to satisfy the needs of the particular application
22 and/or user. It allows the systematic selection and
23 display of any of the available levels of embedded
24 intersection cells.

25 The concept of "matrix abstraction" may be employed
26 with significant benefits in accordance with the
27 present invention. This is because the matrix
28 intersection of catalogs of catalogs represent a
29 catalog of connections, one can abstract very large
30 configurations and display these configurations by
31 displaying the topmost catalog. The matrix

1 representation of the topmost catalog is said to be
2 abstracted from the main or total network matrix.
3 Consider the case when a highest level catalog named
4 *east coast* contains four elements. These four elements
5 are in and of themselves sub-catalogs of cities,
6 namely: *Miami, Atlanta, Durham, Hawthorn*. Assume that
7 each of these cities have three elements. These three
8 elements each further contain 3 elements which are in
9 and of themselves sub-catalogs,

10 [For example, the *Miami* catalog contains elements
11 which are router sub-catalogs, namely: *router 1,*
12 *router 2 router 3;*

13 each of these router sub-catalogs contain 3
14 network elements, e.g., the *router 1* catalog
15 contains network elements, namely: *interface 1,*
16 *subnet w.x.y.z, specific IP address a.b.c.d.]*

17 Then the total number of elements represented by the
18 top-level catalog is $4 \times 3 \times 3 = 36$ elements. This has a
19 total of 1296 (36×36) connection possibilities which
20 may be displayed in a systematic manner using the
21 representation of the present invention. All of these
22 result from the single cell 1×1 matrix of *east coast*
23 versus *east coast* as the specified starting point.
24 Thus, because a user can arbitrarily form catalogs,
25 which can also be catalogs of catalogs, the user can
26 abstract the connections to any level desired in
27 accordance with the present invention.

1 A further benefit of the representation of the present
2 invention is the concept of matrix inheritance. As
3 noted, making use of the abstraction property, one
4 defines a matrix with a row of one or more catalogs
5 versus a column of one or more catalogs. Generally, one
6 or more of the catalogs includes elements that are in
7 and of themselves sub-catalogs. The concept of
8 inheritance provides the ability of propagating an
9 inheritable action and/or attribute to an entire
10 inheritance group. In one embodiment this is
11 accomplished just by performing, adjusting or setting
12 that action/attribute at a group parent. In alternate
13 embodiments the action/attribute is inherited by
14 performing, adjusting or setting that action/attribute
15 at any group member. Thus, when an action (e.g. setting
16 a parameter) is done at a intersection cell, then this
17 action is inherited by all elements of all the
18 sub-catalogs of catalogs in the entire inheritance
19 group.

20 For instance, if the highest level catalog, named *east*
21 *coast*, contains 4 elements which are in and of
22 themselves sub-catalogs, (named: *Miami*, *Atlanta*,
23 *Durham*, *Hawthorn*), and each of these contains 3
24 elements which are in and of themselves sub-catalogs,
25 (e.g., the *Miami* catalog contains *router 1*, *router 2*
26 *router 3*), and each of these contains 3 elements, (e.g.
27 the *router 1* catalog contains elements *interface 1*,
28 *subnet w.x.y.z*, *IP address a.b.c.d*) and a 1x1 matrix of
29 *east coast* versus *east coast* was specified, any action
30 done to the intersection formed by the 1x1
31 (single-cell) matrix (being the group parent) is

1 traffic observed in last observation period, green -
2 medium loading, red - more than 85% utilization,
3 flashing red - excessive packet loss.

4 Figure 10 shows a black and white example of displaying
5 monitored connections using different types of cross
6 hatched lines for different status items. It shows the
7 status indicated by the direction of the slash.

8 1010 (No lines) - no connection configured;

9 1020 (Grid slashes) - connection configured, but
10 not enabled;

11 1030 (Reverse slashes) - connection configured,
12 enabled and operating correctly;

13 1040 (Horizontal slashes) - connection configured,
14 enabled but not operating correctly (e.g. QoS not
15 being maintained);

16 1050 (Vertical slashes) - hacker attempting to
17 insert traffic into the connection. A BEEP
18 indicates an audio alarm is sounded.

19 It is noted that Figure 10 is only an illustration. It
20 is not a comprehensive enumeration of the information
21 that can be displayed. Furthermore, the monitoring and
22 displaying functions are not limited to the
23 connection, but can be extended to the resources that
24 make up the connection or that constitute the end
25 elements, etc. As known to those skilled in the art,

1 the concepts of this invention do not have a dependency
2 on the type of information displayed. For example, it
3 can be dynamic and/or static, fixed or variable, short
4 form or long form, continuous or intermittent, etc.

5 In accordance with the present invention, the
6 connection representation concept is useful among other
7 things, for identifying and solving network operation
8 problems, tuning parameters of network elements and/or
9 connections, and scheduling specific tasks that are
10 triggered by events in the network or simply initiating
11 them directly. This may include actions or tasks for a
12 connections. Thus, since intersections in the matrix
13 can indicate information about connections, one can be
14 provided with an ability to select ("click on") an
15 intersection and initiate an action or task.

16 Example of actions or tasks include:

- 17 • Retrieval of additional information/statistics
18 (such as bytes/sec, size of frames, traffic
19 rate ranked by sending address, etc.)
- 20 • Take action (such as test connectivity between
21 the endpoints, manually refresh the keys, halt
22 traffic, etc.)
- 23 • Tuning one or more connections (such as alter
24 the QoS parameters, change the mix of traffic
25 allowed through the connection, alter buffer
26 sized, etc.)
- 27 • Setting alarms, alerts and/or thresholds to use
28 when monitoring a connection.

1 An example illustrating a problem determination process
2 is shown in Figure 11. Figure 11 uses the connection
3 matrix, 300. One selects an intersection and brings up
4 a display, 910, that aids in problem determination or
5 tuning. This could include the setting of thresholds,
6 etc.

7 An embodiment of the present invention performs
8 modeling as shown in Figure 12. The figure shows steps
9 for the matrix display being used as an input method
10 for modeling tools.

11 Step 1. Using the matrix method described
12 above, 1210, one defines the network to be
13 modeled, 1220, i.e., define the resources
14 (endpoints) and the connectivity between
15 resources;

16 Step 2. Given a matrix of connections, 300, one
17 could select an intersection, 1230, and define
18 the attributes, 1240, of the connection, i.e.
19 maximum frame size, TCP/IP window size, etc.
20 One could also define the attributes of the
21 endpoint, i.e. buffer size, speed, etc.;

22
23 Step 3. Given the matrix of connections and
24 endpoints and their capabilities, one could
25 then:

- 26 • Define a work load to flow through the
- 27 connection and/or between endpoints;

- 1 • Define the rate of traffic to flow
2 through the connection; and/or
3 • Define dynamic aspects of a flow 1250;

4 Step 4 Run the model 1260; and

5 Step 5 Display the results 1270.

- 6 • One could display results in the same
7 method as one monitors the network (see
8 above).
9 • One could display results within the
10 matrix or endpoints.

11 This method describes a way to represent relationships
12 between entities. Given this representation, it then
13 provides a framework to perform actions based on the
14 relationship. The entities are often said to
15 constitute a network of elements. The elements and the
16 network can be quite generic. Examples include:

- 17 • computer networks where the elements are
18 communications devices such as routers or
19 firewalls or combinations of devices;

20 • networks based on any level in a protocol
21 stack, such as applications connectivity at the
22 application layer or MAC (Media Access Control)
23 connectivity at the MAC layer;
24

1 An example of an application is the
2 representation of database applications that
3 have connectivity between themselves;

4 An example of a MAC layer are MAC address
5 domains connected by LAN bridges. Other
6 examples are known to those skilled in the art.
7

8 • IP networks where elements are devices that
9 contain an IP protocol stack;

10 • Switching systems, including data or telephone
11 systems;

12 • Water systems where the elements are the supply
13 points and the usage points; and

14 • Distribution systems where the elements are
15 warehouses and retail stores.

16 The representation method and framework consists of
17 grouping the elements into catalogs or sets. A catalog
18 is created by standard combinatorial operations that
19 include but are not limited to the following:

- 20 • add an element to a catalog;
21 • delete an element from a catalog;
22 • change an element in a catalog;
23 • copy or move an element from another catalog;

1 techniques or other methods known to those skilled in
2 the art. Alternatively, making use of the abstraction,
3 one could form a higher-level abstraction of the
4 elements by forming catalog element(s) that contains at
5 least a portion of the elements and displaying the
6 abstracted catalog elements.

7 If any of the element of a catalog are catalogs in and
8 of themselves, i.e., the element is called a catalog
9 element and it contains sub-elements, the intersection
10 within the matrix of a catalog element with either
11 another catalog element or an atomic element represents
12 both the catalog element and the atomic element
13 relationship abstraction and the sub-elements of that
14 catalog element with the other elements. This can be
15 represented by another matrix, called a sub-matrix,
16 whose axis contain the sub-elements of the catalog
17 element and if present in the original matrix
18 non-catalog elements. It should be recognized within
19 this new sub-matrix, there may be intersections of
20 elements that are catalog elements and this process of
21 creating a new sub-matrix can be repeated. A
22 sub-matrix can be formed when, in the matrix there
23 exists a intersecting cell formed by either a catalog
24 element paired with another catalog element or atomic
25 element.

26 The matrix representation may also be made to represent
27 directionality of the connections between elements.
28 For example, it could be defined that the flow of
29 traffic within a connection originates from the elements
30 on one axis and terminated in the elements of the other

axis. Further, if the same elements were placed on both axes, except for the matrix diagonal, each pair of elements (one member of the pair from one axis, the other member of the pair from the other axis) would be represented twice, i.e., {a,b} and {b,a}. If the matrix was constructed to represent directionality, each pair would explicitly show the flow in one direction, {a,b} from a to b and {b,a} from b to a.

If in the matrix, an element on an axis is in and of itself a catalog, then the connection relationship represented by a matrix intersection cell associated with that catalog element applies to all sub-elements represented by the catalog element.

Catalogs do not have to be unique, either in their structure or their members, i.e., two or more catalogs can have identical sets of elements. Furthermore, two catalogs may have only a portion of their elements that are identical. Also, when defining the matrix, the same catalog can be used for specifying elements on both the axes or two catalogs can be used, one for each axis. In the former case, obviously, elements on one axis are identical to those on the other. However, the same configuration will also result when two catalogs are used that have identical composition. In general, elements on the two axes of the matrix may have none, some or all of the elements that are common depending on how catalogs are chosen for the axis.

This method can be used to represent a wide variety of networks used in communication, including virtual

1 networks and overlay networks. Virtual networks are
2 often formed by logically partitioning a network's
3 physical connectivity to give the appearance of a
4 physical network that is a logical subset of the real
5 network. Overlay networks are sometimes synonymous
6 with virtual networks, in that a logical network is
7 "overlayed" onto a physical network or a portion of a
8 physical network. More generally, an overlay network is
9 an abstraction of a subset of the real network that is
10 defined by availability of specific service. Examples
11 of these types of networks include but are not limited
12 to:

- 13 • IPsec networks which provide secure "tunnels"
14 between points in the network,
- 15 • Quality of Service (QoS or QOS) networks which
16 attempt to provide a class or quality of
17 service for the traffic between points in the
18 network.
- 19 • Multiprotocol Label Switching (MPLS) networks
20 which use MPLS methods to set up paths through
21 the network.
- 22 • Virtual LAN (VLAN) networks which form logical
23 LAN(s) based on a subset of the connectivity
24 available in the real physical LANs.

25 This method can be used to configure all of the
26 possible connections between the catalogs or it can be
27 used to configure a portion of the connections.

1 This method can also be used to associate tasks with a
2 connection. Any of tasks can be specified to be
3 executed as a result of change in the state of a
4 connection or at a predetermined time or on occurrence
5 of some other event. Tasks can also be formed to
6 modify themselves or other tasks. Once such tasks are
7 assigned, it is also possible to directly invoke any of
8 such tasks through manual intervention. For example,

- 9 • at a defined time or time period, one could
10 invoke a task that changed the attributes of
11 the connection, i.e. at 5:00 each day, all
12 traffic is blocked.
- 13 • at a defined state or rate of change of state,
14 one could invoke a task that changed the
15 attributes of the connection, i.e., if the
16 throughput of the connection exceeds "n", then
17 lower the priority of all packets that traverse
18 the connection or if the rate of change of
19 utilization of the link is greater than 5% per
20 minute, activate another link between the
21 endpoints.
- 22 • at a given change in state, such as an
23 unauthorized attempt to access a resource or a
24 link failure, one could invoke a task that sent
25 an alert to network or system management entity
26 or cause a page or fax notification to be sent.
- 27 • as part of a diagnostic or maintenance test,
28 network administrator may manually invoke an
29 assigned task, for example shutting down a
30 router, or disabling a feature

1 (RSVP/IPSEC/Filtering) on a particular router
2 interface.

3 An element in a catalog (note that an element can be a
4 catalog in and of itself) or the representation of the
5 connection indicated by the intersection of elements
6 can be an abstract entity. The element can represent
7 an abstraction of physical or nonphysical items.
8 Examples of physical items are routers, gateways,
9 firewalls. Examples of nonphysical items include the
10 IP addresses or IP subnets associated with a router, IP
11 addresses or IP subnets proxied for by a router, groups
12 of users, groups of addresses, attributes of
13 connections or physical devices. Abstract elements
14 also include offerings of services such as quality of
15 service offerings, security offerings, assured delivery
16 and expedited delivery offerings, controlled load
17 services, and service level agreements. Abstract
18 elements can include attributes such as tunnel validity
19 periods, DES, triple DES, RC4, SHA, buffer size,
20 maximum frame size, application type. Other examples
21 are known to those skilled in the art.

22 A method of displaying the connection relationships
23 using a matrix has been discussed. In some cases, one
24 will display the complete matrix, in others, one may
25 display a portion of the matrix. Note that to those
26 skilled in the art, there are other ways to display a
27 matrix than the ones illustrated in this write-up.

28 Given that the intersection of two elements is a
29 representation of information either about the

1 If there is one element in a catalog and multiple
2 elements in another catalog, the resulting matrix can
3 be said to represent a star network because the
4 representation of the connectivity is between the one
5 element and the multiple elements, a one-to-many
6 topology. If there are multiple elements or there is an
7 element that is in and of itself a catalog of elements
8 in the catalogs that are positioned along the axis of
9 the matrix, the resulting matrix can be said to
10 represent a mesh network, because the representation of
11 the connectivity is between multiple elements on each
12 axis and there is a connection between each element on
13 one axis to every element on the other axis.

14 A wizard is a tool that aids a person doing a task.
15 Wizards are used to create catalog elements or
16 attributes associated with an element or group of
17 elements. Wizards are also used to aid the creation or
18 deletion of a connection or the modification of an
19 attribute of the connection. For example, a wizard may
20

- 21 • assist in organizing a catalog;
- 22 • setting the initial values of attributes;
- 23 • help by generating context sensitive templates
24 for the elements or their attributes;
- 25 • assist in defining the relationships between
26 elements;
- 27 • setting the initial configuration between
28 elements; setting the ongoing relationship or
29 configuration between elements; and

1 • and any other tasks known to those skilled in
2 the art.

3 When the matrix representation is formed, the
4 connections between the elements can be initialized to
5 connected by default. In a later configuration step,
6 connections that are not desired can be removed. They
7 may be removed by direct action or with the use of a
8 wizard. Likewise, when the matrix representation is
9 formed, the connections between the elements can be
10 initialized to an unconnected state. In a later
11 configuration step, connections that are desired can be
12 added by direct action or with the use of a wizard.
13 Likewise, when the matrix representation is formed,
14 connections can be initialized by rule. For example,
15 connections designated as primary may be formed, all
16 others are not. Note that the use of a wizard to add
17 or remove connections is not dependent on the
18 initialization process.

19 This invention has the property of inheritance, both at
20 the element and at the connection representation
21 levels. Thus, if an element is in an of itself a
22 catalog, i.e. the element is formed from sub-elements,
23 when an inheritable change is made to an element's
24 attribute, the change is propagated or inherited by
25 the sub-elements. For example, if a catalog had
26 elements { A, B, C} and element A was a catalog
27 containing {A1, A2, A3}. Then an inheritable change in
28 A is propagated to A1, A2 and A3. Because A1, A2 and
29 A3 can be catalogs in and of themselves, the

1 sub-elements that compose them could also receive the
2 change made by A. Because there is no restriction that
3 a element must not be a catalog, there is no
4 restriction on the number of times this principle can
5 be applied. Likewise, if a connection representation
6 was formed from elements that are in and of themselves
7 catalogs, changes in the connection representation are
8 inherited by all connections representations that can
9 be derived from the elements of the all the catalogs of
10 catalogs. For example, assume the highest level
11 catalog, named *east_coast*, contained 4 elements which
12 were in and of themselves catalogs, named: *Miami*,
13 *Atlanta*, *Durham*, *Hawthorn*, and each of these contained
14 3 elements which were in and of themselves catalogs,
15 e.g., the *Miami* catalog contained *router_1*, *router_2*,
16 *router_3*, and each of these contained 3 elements, e.g.
17 the *router_1* catalog contained elements *interface_1*,
18 *subnet_w.x.y.z*, *IP_address_a.b.c.d*. Now, if a 1x1
19 matrix of *east_coast* versus *east_coast* was specified
20 and an action was done to that intersection formed by
21 the 1x1 matrix, this action would cause a change in all
22 connection representations that can be derived from the
23 elements of the catalogs of catalogs. Examples of
24 actions are the setting of a security policy or a
25 quality of service. Other examples are known to those
26 skilled in the art. In a similar manner, if an
27 attribute of all derivable connection representations
28 or elements was the same for all the connection
29 representations or elements and an attribute of a
30 connection representation or an element was changed,

1 this change could be reflected in the representation of
2 the catalog element or the abstracted connection
3 representation. For example, if the highest level
4 catalog, named *east_coast*, contained 4 elements which
5 were in and of themselves catalogs, named: *Miami*,
6 *Atlanta*, *Durham*, *Hawthorn*, and each of these contained
7 3 elements which were in and of themselves catalogs,
8 e.g., the *Miami* catalog contained *router_1*, *router_2*
9 *router_3*, and each of these contained 3 elements, e.g.
10 the *router_1* catalog contained elements *interface_1*,
11 *subnet_w.x.y.z*, *IP_address_a.b.c.d* and a 1x1 matrix of
12 *east_coast* versus *east_coast* was specified in which
13 an attribute was the same for all derivable connections
14 representations and one of the connections
15 representation's attribute was changed (e.g.,
16 *east_coast/router_1/interface_1* was set to no
17 connection), the catalog's representation (e.g.,
18 *east_coast*) could indicate that the attribute was not
19 homogeneously applied to all of the derivable
20 connections representations. In a converse manner, if
21 an element was a catalog element containing
22 sub-elements, all derivable sub-elements would inherit
23 the attributes of their "parent" element. If an
24 attribute was not homogeneously applied (inherited
25 by all sub-elements) to all elements, the catalog
26 element representation could indicate that the
27 attribute was not homogeneously applied to (inherited
28 by) all derivable sub-elements. Note that a
29 sub-element can itself be a catalog and contain
30 sub-elements.

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1 These techniques can be extended beyond the
2 configuration and administration tasks to monitoring at
3 least some portion of the network. In addition to
4 attribute type information for elements or the
5 representation of the connection, one can display
6 monitoring information about the elements or the
7 representation of the connection. For example, one
8 could show, at the matrix intersection, the status of a
9 connection. Examples of status include: whether the
10 connection is active or not, the throughput of the
11 connection, the number of dropped packets/frames due to
12 a quality of service definition. One can also show
13 status associated with the elements at the edge of the
14 matrix. Examples of status include: number of frames
15 transmitted, number of attempts by an unauthorized
16 entity to access the element, average size of outbound
17 buffer used, number of configured tunnels, number of
18 active tunnels. Status can be dynamic or static. The
19 monitored information may be displayed in the form of
20 text, graphics or audio. Examples include a text that
21 is color coded per the status information; for example,
22 a correctly functioning connection may be displayed in
23 a color, such as green, while a failed connection may
24 be displayed in a color such as red. An intrusion
25 attempt may cause an audible alarm. A change in the
26 performance of a connection may be shown. Status for a
27 connection could show a bar graph of the utilization of
28 the connection by connection type. Many other examples
29 of monitoring the status and methods of displaying the
30 information are known to those skilled in the art.

1 These techniques can be extended beyond the
2 configuration, administration and monitoring tasks to
3 modeling at least some portion of the network. Since
4 the matrix can be used to represent connectivity
5 between elements and the elements can be used to
6 represent workload that the connection will experience,
7 one can use the same network representation to model a
8 network. Attributes of a connection may be specified
9 at the intersection point. The attributes define the
10 type of service the connection offers, such as the
11 number of servers, the server's service time
12 distribution, and the maximum system capacity.
13 Attributes of a workload may include the size of the
14 packet, the interarrival time distribution, and the
15 priority of the packet. Other attributes for the
16 connection and workload are known to those skilled in
17 the art. One can form or derive the network to be
18 modeled from the configuration and/or monitoring
19 methods previously discussed. One can also derive the
20 workloads from the monitoring steps previously
21 discussed. In this way, one can model an existing
22 network and perform investigation based on real or
23 projected network loading and real or projected network
24 configuration. For example, given a network model
25 derived from the real network, one could apply
26 projected workloads to the "real" network and observe
27 the effects on the "real" network. Likewise, one
28 could, given workloads derived from monitoring the real
29 network, apply these "real" workload to a modified
30 network and observe the effects on the "real" workload.
31 One could also export or import information into/out of
32 the model.

1 network catalogs has a connection requirement with each
 2 network element of a second subset of network catalogs.
 3 Each network element of the first subset of network
 4 catalogs forms the matrix row element. Each network
 5 element of a second subset of network catalogs forms
 6 the matrix column elements. Each matrix cell
 7 represents a network connection between each network
 8 element of the first catalog and each network element
 9 of the second catalog.

10 In an embodiment at least one network element is a
 11 catalog of sub-elements, and/or at least one of the
 12 sub-elements is another catalog of sub-elements. and/or
 13 the matrix module further forms a network submatrix
 14 having at least one submatrix row element and at least
 15 one submatrix column element. The intersection of each
 16 said at least one submatrix row element with each said
 17 at least one sub-matrix column element forms a
 18 submatrix cell. Each network element of a third subset
 19 of network catalogs has a connection requirement with
 20 each element of a fourth subset of network catalogs.
 21 Each element of the third subset of network catalogs
 22 forms a submatrix row element, and each network element
 23 of the fourth subset of network catalogs forms the
 24 submatrix column element. Each submatrix cell
 25 represents a network connection between each network
 26 element of the third catalog and each network element
 27 of the fourth catalog.

28 In a further embodiment the apparatus includes an
 29 attribute modifier module to modify at least one
 30 changeable attribute of at least one cell. In some

1 cases the attribute modifier further causes an
2 inheritable change to be inherited by a group of
3 inheritors; and/or a first network element is a first
4 proxy; a second element is a second proxy, and the
5 attribute is setting a Quality of Service, and the step
6 of causing causes the Quality of Service policy to be
7 set at all elements included in the first and second
8 proxies; and/or a first element is a catalog of
9 sub-elements, the attribute is setting an encryption
10 policy, and the step of causing causes the encryption
11 policy to be set at all sub-elements of the first
12 element.

13 The invention may further be implemented as a method
14 comprising: forming a network matrix having at least
15 one matrix row element and at least one matrix column
16 element; forming a matrix cell at each intersection of
17 each matrix row element with each matrix column
18 element; and forming a plurality of network catalogs;
19 listing at least one network element in each of the
20 catalogs; setting the network element of the catalogs
21 to be the matrix row elements; setting a network
22 element of at least one of the catalogs to be the
23 matrix column elements, and forming a representation of
24 a connection requirement of each respective matrix row
25 element with each respective matrix column element
26 which form each particular matrix cell by the
27 particular matrix cell.

28 In some embodiments of the method at least one matrix
29 row element is a sub-catalog listing at least one
30 sub-catalog network element; and/or the method further

1 CLAIMS

2 What is claimed is:

3 1. A method for representing interconnection of a
4 plurality of elements on a network, the method
5 comprising:

6 providing a first catalog for a first subset of
7 said elements, and providing a second catalog for
8 a second subset of said elements;

9 creating a matrix of connection cells formed by an
10 intersection of a pair of elements, wherein a
11 first element of each pair is taken from the first
12 catalog and a second element of each pair is taken
13 from the second catalog; and

14 forming a connection representation for at least a
15 subset of the pairs.
16

17 2. A method as recited in claim 1, wherein at least one
18 element is a catalog of sub-elements, and the method
19 further comprises the step of including all
20 sub-elements in the matrix.

21 3. A method as recited in claim 1, wherein the network
22 is a communications network and at least a subset of
23 the elements includes routers.

1 4. A method as recited in claim 1, wherein the network
2 is an IP network and at least a subset of said elements
3 have an IP protocol stack.

4 5. A method as recited in claim 1, wherein at least one
5 particular element in the first catalog is the same as
6 a particular element in the second catalog.

7 6. A method as recited in claim 1, wherein at least one
8 of the catalogs includes a plurality of sub-catalogs.

9 7. A method as recited in claim 1, wherein at least a
10 portion of the network is a computer network.

11 8. A method as recited in claim 1, wherein at least a
12 portion of the network is a virtual network.

13 9. A method as recited in claim 1, wherein at least a
14 portion of the network is a network implemented using a
15 layer above a physical layer.

16 10. A method as recited in claim 1, wherein at least a
17 portion of the network is an overlay network.

18 11. A method as recited in claim 10, wherein at least a
19 portion of the overlay network is an IPSec network.

20 12. A method as recited in claim 10, wherein at least a
21 portion of the overlay network provides Quality of
22 Service.

- 1 22. A method as recited in claim 1, wherein at least
2 one of the elements is a physical entity.
- 3 23. A method as recited in claim 1, further comprising
4 displaying at least one portion of the matrix.
- 5 24. A method as recited in claim 1, further comprising
6 monitoring at least one portion of the matrix.
- 7 25. A method of claim 1, wherein the matrix is
8 structured such that elements of a row are different
9 from elements of a column.
- 10 26. A method of claim 25, wherein at a least a portion
11 of the connections form a star network.
- 12 27. A method of claim 1, wherein the matrix is
13 structured such that elements on a the row are
14 identical to elements on a column.
- 15 28. A method of claim 27, wherein at a least a portion
16 of the connections form a mesh network.
- 17 29. A method as recited in claim 2, wherein at least
18 another element is a second catalog of sub-elements and
19 the method further comprises the step of forming a
20 sub-matrix of said one element with said another
21 element.
- 22 30. A method as recited in claim 1, further comprising
23 employing a wizard to form at least a subset of the
24 elements.

- 1 31. A method as recited in claim 1, further comprising
2 initializing all connections to a connected state.
- 3 32. A method as recited in claim 1, further comprising
4 employing a wizard to determine which connections to be
5 brought to a connected state.
- 6 33. A method as recited in claim 1, further comprising
7 initializing all connections to a non-connected state.
- 8 34. A method as recited in claim 1, further comprising
9 choosing at least one pair upon which a manipulation is
10 performed.
- 11 35. A method as recited in claim 34, further comprising
12 modifying at least one changeable attribute of the
13 connection.
- 14 36. A method as recited in claim 35, further comprising
15 causing an inheritable change to be inherited by a
16 group of inheritors.
- 17 37. A method as recited in claim 36, wherein a first
18 element is a first gateway, a second element is a
19 second gateway, and the attribute is setting a security
20 policy, and the step of causing causes the security
21 policy to be set at all elements included in the first
22 and second gateway.
- 23 38. A method as recited in claim 36, wherein a first
24 element is a catalog of sub-elements, and the attribute

1 is setting a Quality of Service policy, and the step of
2 causing causes the Quality of Service policy to be set
3 at all sub-elements of the first element.

4 39. A method as recited in claim 6, wherein a
5 sub-catalog includes other sub-catalogs.

6 40. A method as recited in claim 1, further comprising
7 monitoring at least a portion of a network state in
8 accordance with the representation.

9 41. A method as recited in claim 40, further comprising
10 displaying at least a portion of the network state.

11 42. A method as recited in claim 41, wherein the step
12 of displaying includes employing color codes for
13 showing attributes.

14 43. A method as recited in claim 1, further comprising
15 the step of modeling connections.

16 44. A method as recited in claim 41, further comprising
17 indicating changes in performance in response to an
18 occurrence.

19 45. A method as recited in claim 1, wherein a least one
20 element of a particular pair is a sub-catalog, the
21 method further comprising expanding elements of the
22 pair into a sub-matrix.

23 46. An article of manufacture comprising a computer
24 usable medium having computer readable program code

1 means embodied therein for causing an interconnection
2 representation of a plurality of elements on a network,
3 the computer readable program code means in said
4 article of manufacture comprising computer readable
5 program code means for causing a computer to effect:

6 providing a first catalog for a first subset of
7 said elements, and providing a second catalog for
8 a second subset of said elements;

9 creating a matrix of connection cells formed by an
10 intersection of a pair of elements, wherein a
11 first element of each pair is taken from the first
12 catalog and a second element of each pair is taken
13 from the second catalog; and

14
15 forming a connection representation for at least a
16 subset of the pairs.

17 47. An article of manufacture as recited in claim 46,
18 wherein at least one element is a catalog of
19 sub-elements, and the method further comprises the step
20 of including all sub-elements in the matrix.

21 47. An article of manufacture as recited in claim 46,
22 wherein the network is a phone network and at least a
23 subset of the elements includes switches.

24 48. An article of manufacture as recited in claim 46,
25 the computer readable program code means in said
26 article of manufacture further comprising computer
27 readable program code means for causing a computer to

1 effect configuring at least a portion of the network
2 employing the representation.

3 49. An article of manufacture as recited in claim 46,
4 the computer readable program code means in said
5 article of manufacture further comprising computer
6 readable program code means for causing a computer to
7 effect associating at least one task with at least one
8 connection.

9 50. An article of manufacture as recited in claim 49,
10 the computer readable program code means in said
11 article of manufacture further comprising computer
12 readable program code means for causing a computer to
13 effect triggering at least said one task as a result of
14 a change of a state of said one connection.

15 51. An article of manufacture as recited in claim 46,
16 the computer readable program code means in said
17 article of manufacture further comprising computer
18 readable program code means for causing a computer to
19 effect choosing at least one pair upon which a
20 manipulation is performed.

21 52. An article of manufacture as recited in claim 51,
22 the computer readable program code means in said
23 article of manufacture further comprising computer
24 readable program code means for causing a computer to
25 effect modifying at least one changeable attribute of
26 the connection.

1 53. An article of manufacture as recited in claim 52,
2 the computer readable program code means in said
3 article of manufacture further comprising computer
4 readable program code means for causing a computer to
5 effect causing an inheritable change to be inherited by
6 a group of inheritors.

7 54. A network architecture comprising:

8 a matrix module forming a network matrix having at
9 least one matrix row element and at least one matrix
10 column element, an intersection of each said at least
11 one matrix row element with each said at least one
12 matrix column element forming a matrix cell;

13 a set of network elements, a first subset of said set
14 having a connection requirement with a second subset of
15 said set;

16 a first catalog including at least one network element
17 forming said at least one matrix row element; and

18 a second catalog including at least one network element
19 forming said at least one matrix column element,
20 wherein each matrix cell represents a network
21 connection between each network element of the first
22 catalog and each network element of the second catalog
23 to enable systematic cooperation among network elements
24 according to a network requirement.

25 55. An architecture as recited in claim 54, wherein at
26 least one network element is a catalog of sub-elements.

1 56. An architecture as recited in claim 55, wherein at
2 least one of said sub-elements is another catalog of
3 sub-elements.

4 57. An architecture as recited in claim 55, further
5 comprising a sub-matrix module forming a network
6 sub-matrix having at least one sub-matrix row element
7 and at least one sub-matrix column element, an
8 intersection of each said at least one sub-matrix row
9 element with each said at least one sub-matrix column
10 element forming a sub-matrix cell;

11 at least one network element of at least a first
12 catalog forming said at least one sub-matrix row
13 element; and

14 at least one network element of at least a second
15 catalog forming said at least one sub-matrix column
16 element, such that each sub-matrix cell represents the
17 network connection between a first particular network
18 element of the first catalog and a second particular
19 network element of the second catalog.

20 58. An architecture as recited in claim 55, further
21 comprising a sub-matrix catalog module for including
22 all sub-matrix row and column elements in the network
23 matrix.

24 59. An architecture as recited in claim 54, wherein
25 the network is a water distribution network and at

1 least a subset of the elements includes at least one
2 water main.

3 60. An architecture as recited in claim 54, wherein at
4 least one network element in the first catalog is the
5 same as another network element in the second catalog.

6 61. An architecture as recited in claim 54, wherein at
7 least one network element is a software element.

8 62. An architecture as recited in claim 54, wherein at
9 least one catalog is a software module.

10 63. An architecture as recited in claim 54, wherein
11 said first subset is identical to said second subset.

12 64. An architecture as recited in claim 54, further
13 comprising a combiner wherein at least a portion of one
14 catalog is formed using combinatorial operations upon
15 elements of the other catalog.

16 65. An architecture as recited in claim 54, further
17 comprising an associator for associating at least one
18 task with at least one connection.
19 , further comprising displaying at least one portion of
20 the matrix.

21 66. An architecture as recited in claim 54, further
22 comprising a monitor coupled to the network matrix to
23 monitor at least one portion of the network matrix.

1 67. An architecture as recited in claim 54, wherein
2 the matrix is structured such that elements of a row
3 are different from elements of a column.

4 68. An architecture as recited in claim 55, wherein at
5 least another element is a second catalog of
6 sub-elements and the matrix module forms a sub-matrix
7 of said one element with said another element.

8 69. A method as recited in claim 1, wherein at least
9 one element is a router.

10 70. An network apparatus comprising:
11 a matrix module forming a network matrix having at
12 least one matrix row element and at least one
13 matrix column element, an intersection of each
14 said at least one matrix row element with each
15 said at least one matrix column element forming a
16 matrix cell, and

17 a plurality of network catalogs, each of the
18 catalogs listing at least one network element,

19 wherein each said at least one network element of a
20 first subset of network catalogs has a connection
21 requirement with another element of said at least one
22 network element of a second subset of network catalogs,
23

24 each said at least one network element of the first
25 subset of network catalogs forming said at least one
26 matrix row element,

1 each said another element of said at least one network
2 element of a second subset of network catalogs forming
3 said at least one matrix column element, and

4 each matrix cell represents a network connection
5 between each network element of the first catalog and
6 each network element of the second catalog.

7 71. An apparatus as recited in claim 70, wherein at
8 least one network element is a catalog of sub-elements.

9 72. An apparatus as recited in claim 71, wherein at
10 least one of said sub-elements is another catalog of
11 sub-elements.

12 73. An apparatus as recited in claim 71, wherein the
13 matrix module further forms a network submatrix having
14 at least one submatrix row element and at least one
15 submatrix column element, an intersection of each said
16 at least one submatrix row element with each said at
17 least one sub-matrix column element forming a submatrix
18 cell;

19 each said at least one network element of a third
20 subset of network catalogs has a connection requirement
21 with another element of said at least one network
22 element of a forth subset of network catalogs,

23 each said at least one network element of the third
24 subset of network catalogs forming said at least one
25 submatrix row element,

1 each said another element of said at least one network
2 element of the fourth subset of network catalogs
3 forming said at least one submatrix column element, and

4 each submatrix cell represents a network connection
5 between each network element of the third catalog and
6 each network element of the fourth catalog.

7 74. An apparatus as recited in claim 73, wherein said
8 third subset is a particular element included in said
9 first subset.

10 75. An apparatus as recited in claim 74, wherein said
11 fourth subset is another particular element included in
12 said second subset.

13 76. An apparatus as recited in claim 73, wherein at
14 least one network element of the third subset has a
15 connection requirement with at least one network
16 element of the first subset, and

17 each said at least one network element of the third
18 subset is included in said at least one network matrix
19 row element.

20 77. An apparatus as recited in claim 76, wherein at
21 least one network element of the fourth subset has a
22 connection requirement with at least one network
23 element of the second subset, and

each said at least one network element of the fourth subset is included in said at least one network matrix column element.

78. An apparatus as recited in claim 70, wherein at least one network element of the first subset is identical with one network element in the second subset.

79. An apparatus as recited in claim 73, wherein at least one network element of the third subset is identical with one network element in the fourth subset.

78. An apparatus as recited in claim 70, further comprising an attribute modifier module to modify at least one changeable attribute of at least one cell.

79. An apparatus as recited in claim 78, wherein the attribute modifier further causing an inheritable change to be inherited by a group of inheritors.

80. An apparatus as recited in claim 79, wherein a first network element is a first proxy, a second element is a second proxy, and the attribute is setting a Quality of Service, and the step of causing causes the Quality of Service policy to be set at all elements included in the first and second proxies.

81. An apparatus as recited in claim 79, wherein a first element is a catalog of sub-elements, and the attribute is setting an encryption policy, and the step

1 of causing causes the encryption policy to be set at
2 all sub-elements of the first element.

3 82. An method comprising:

4 forming a network matrix having at least one
5 matrix row element and at least one matrix column
6 element,

7 forming a matrix cell at each intersection of each
8 said at least one matrix row element with each
9 said at least one matrix column element, and

10 forming a plurality of network catalogs;

11 listing at least one network element in each of
12 the catalogs;

13 setting said at least one network element of at
14 least one of the catalogs to be said at least one
15 matrix row element;

16 setting said at least one network element of at
17 least one of the catalogs to be said at least one
18 matrix column element, and

19 forming a representation of a connection
20 requirement of each respective matrix row element
21 with each respective matrix column element forming
22 each particular matrix cell by said particular
23 matrix cell.

1 83. A method as recited in claim 82, wherein at least
2 one matrix row element is a sub-catalog listing at
3 least one sub-catalog network element.

4 84. A method as recited in claim 82, further
5 comprising including said at least one sub-catalog
6 network element within said at least one matrix row
7 element.

8 85. A method as recited in claim 82, further
9 comprising employing the representation in an operation
10 selected from the group consisting of displaying,
11 inheriting, configuring, administering, monitoring,
12 modeling and any combination of these operations.

13 86. A method as recited in claim 82, wherein the step
14 of forming a representation of a connection includes
15 indicating a directionality of the connection.

16 87. A method as recited in claim 1, wherein the step of
17 forming a connection representation for at least a
18 subset of the pairs includes indicating a
19 directionality of the connection.

1 REPRESENTING, METHOD OF CONFIGURING,
2 ADMINISTERING, MONITORING, AND/OR MODELING
3 CONNECTIONS USING CATALOGS AND MATRIXES

4 ABSTRACT OF THE INVENTION

5 A method, apparatus, computer product and structure is
6 presented for representing and managing large amounts
7 of information concerning networks of elements. While
8 being useful for communication networks, it can be also
9 usefully deployed in the context of other networks such
10 as distribution and transportation networks. The method
11 uses a hierarchical construct called "catalog" - a set
12 of elements (which could be "atomic" elements or
13 catalogs themselves) - to organize information about
14 physical or abstract entities relevant for modeling the
15 network. A matrix construct whose rows and columns
16 constitute such elements are used to model connections
17 at different levels of abstraction. A common framework
18 and representation provided using these two constructs
19 is shown to be useful for visualization,
20 administration, configuration, modeling, monitoring and
21 manipulation of the network.

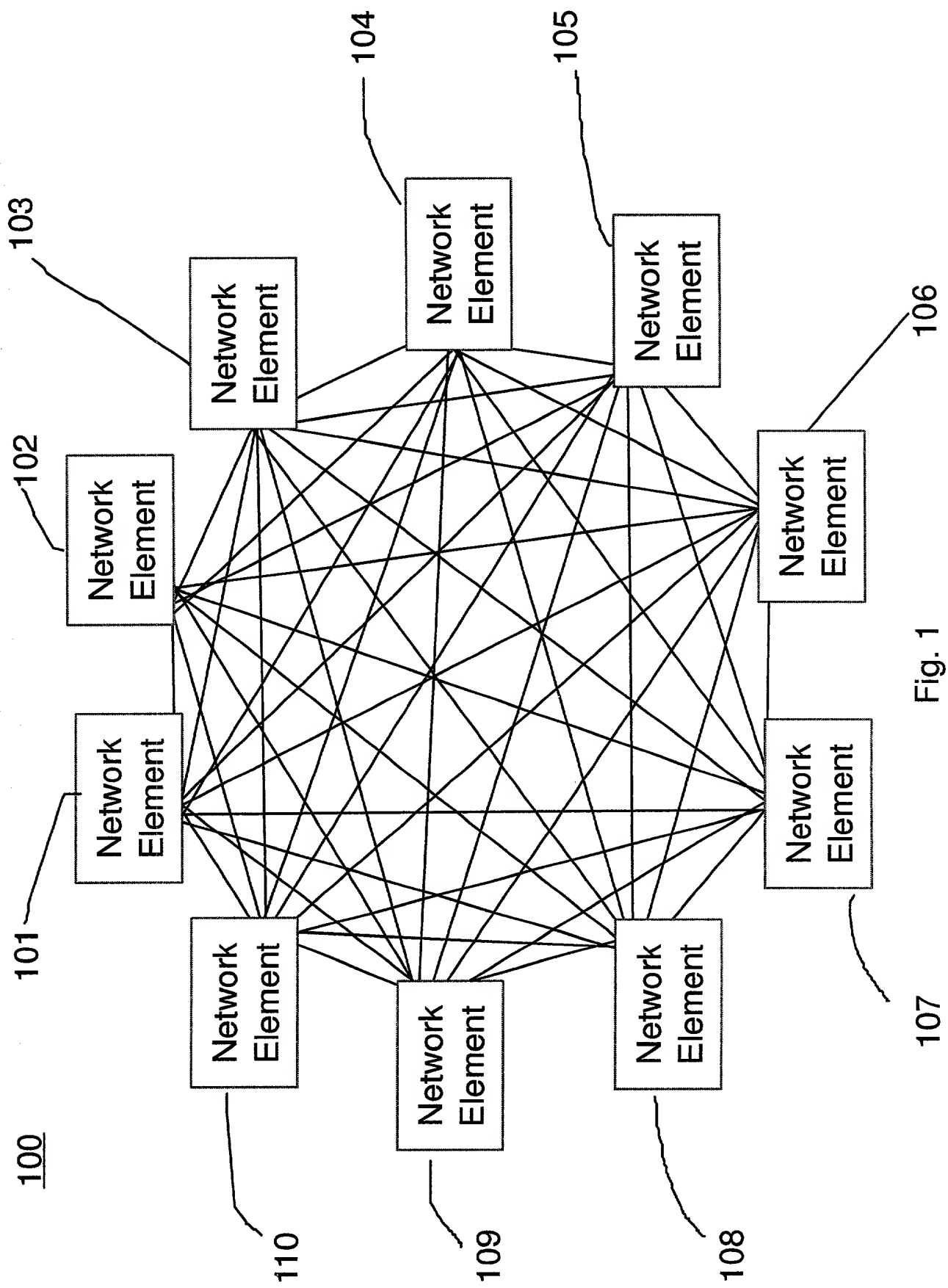


Fig. 1

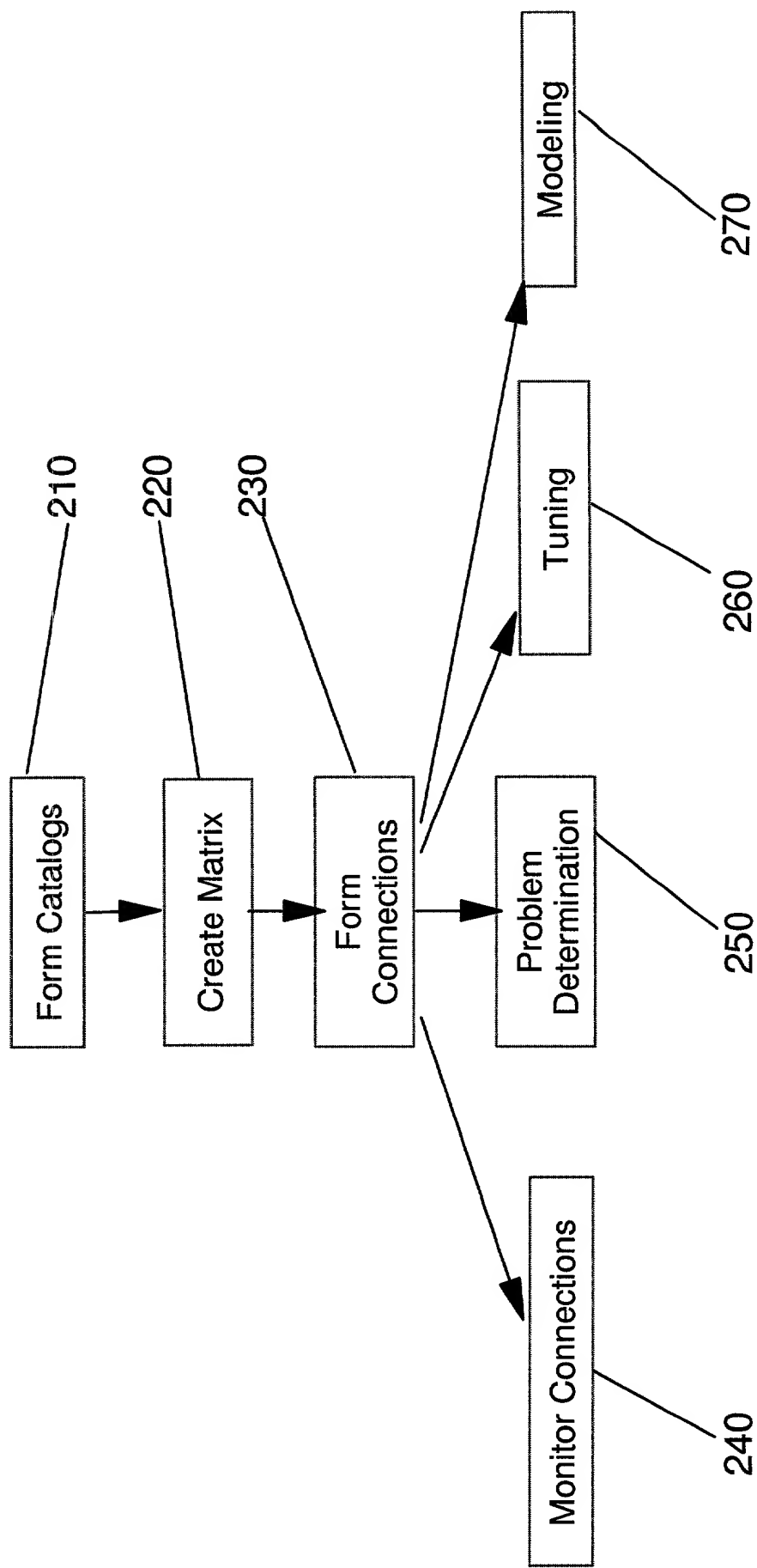


Fig. 2

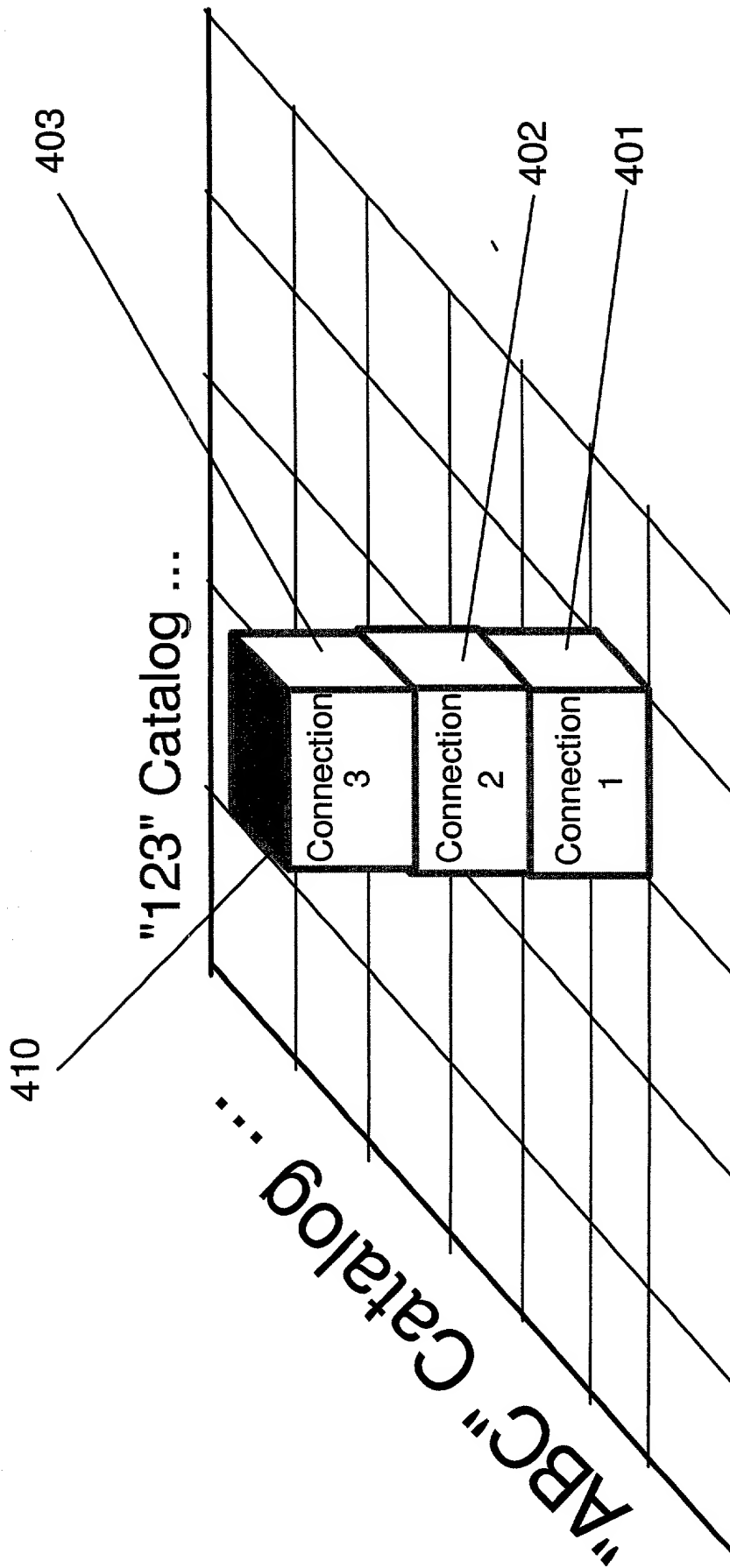


Fig. 4

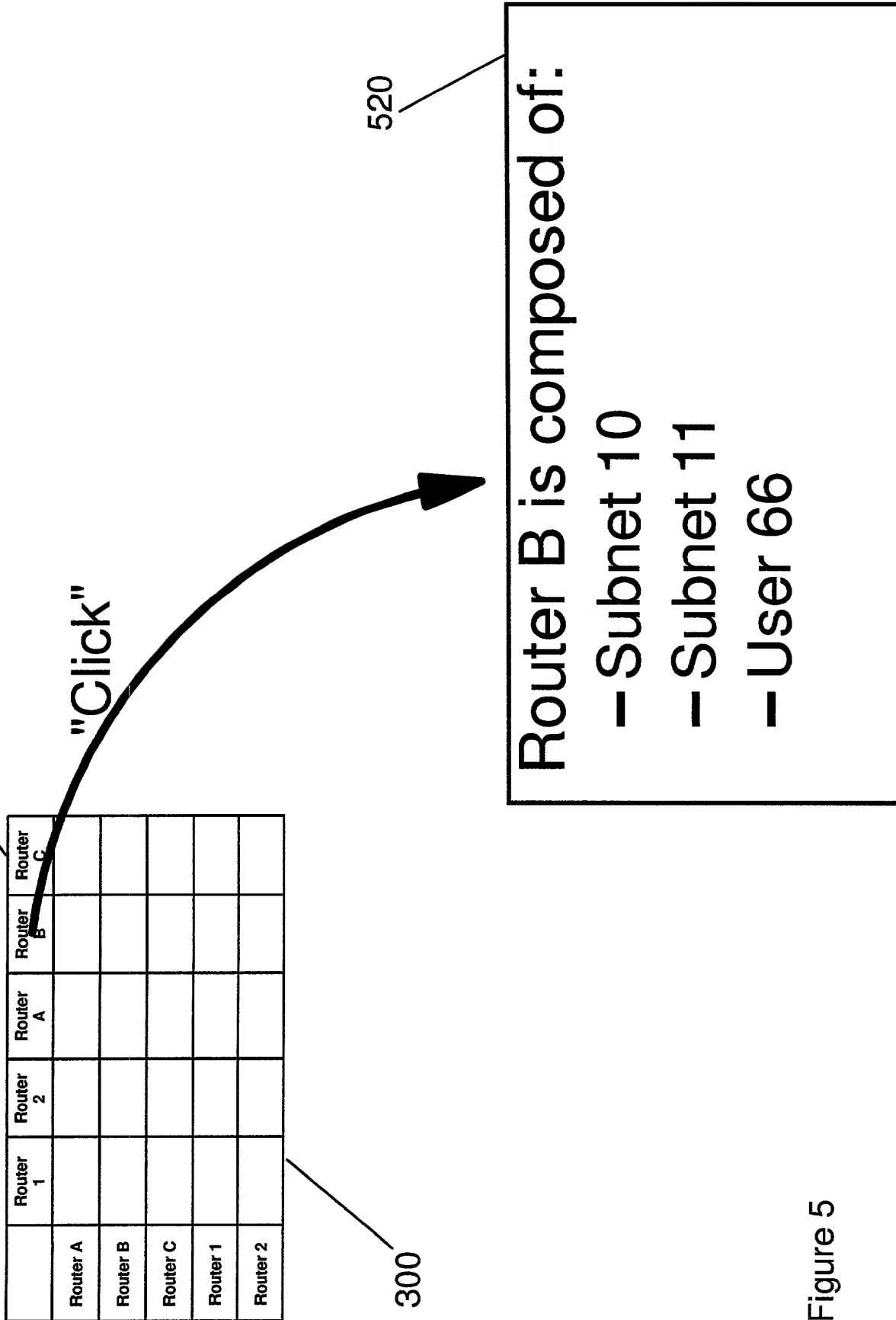


Figure 5

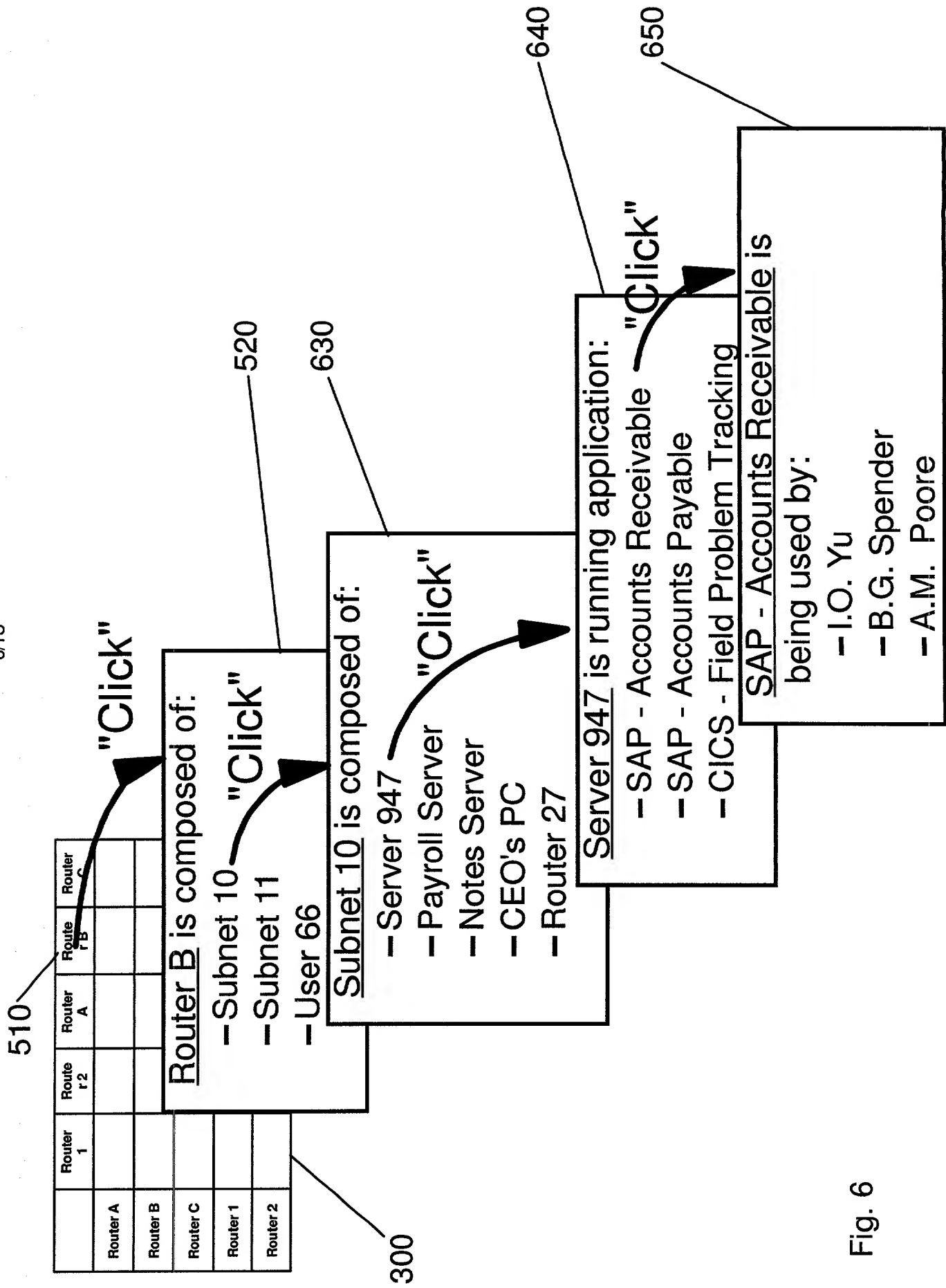


Fig. 6

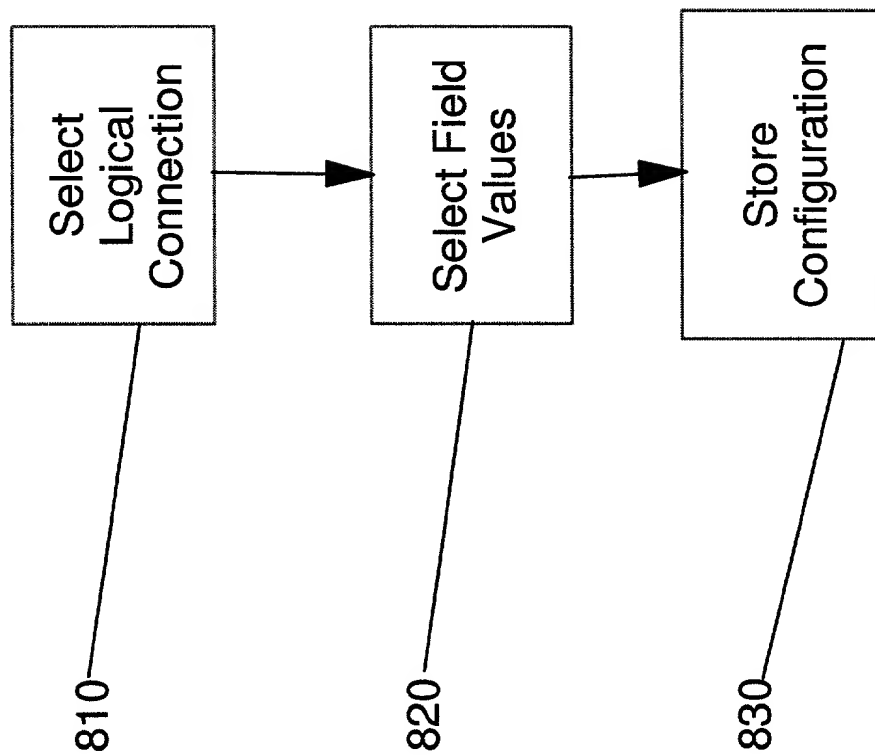
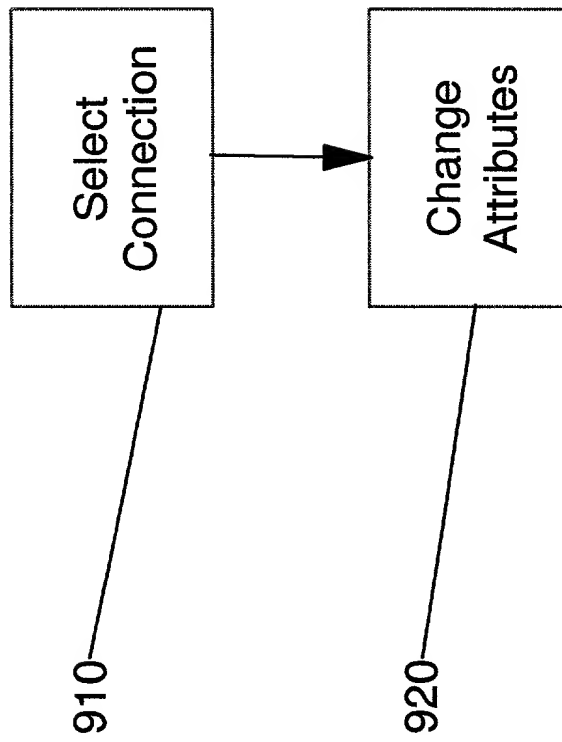


Fig. 8



300

320

"123" Catalog of Endpoints

1050

310 "ABC" Catalog of Endpoints

	Endpoint 1	Endpoint 2	Endpoint 3	Endpoint 4	Endpoint 5	Endpoint 6	Endpoint 7
Endpoint A				BEEP!! BEEP!! BEEP!!			
Endpoint B							
Endpoint C							
Endpoint D							
Endpoint E							
Endpoint F							
Endpoint G							

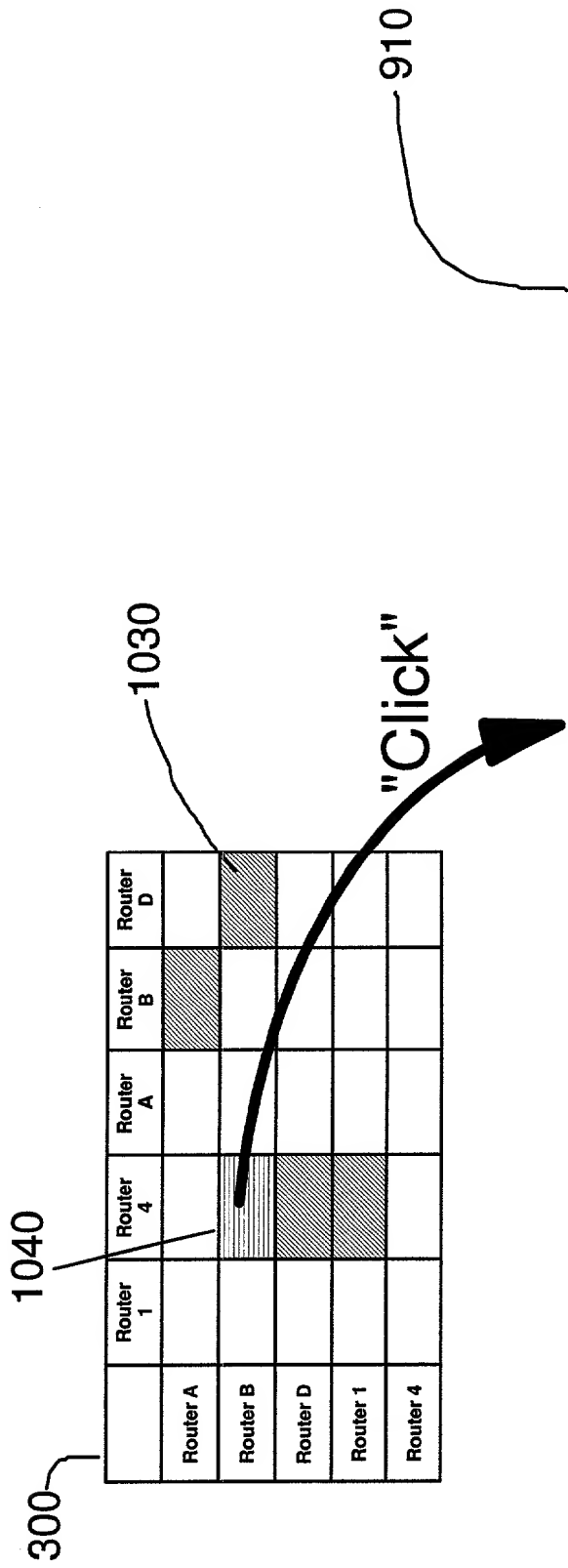
Fig. 10

1040

1030

1010

1020



Connection B4 -- No data traffic
observed for last hour.

- ☐ Ping from endpoint to endpoint.
- ☐ Close Connection
- ☐ Restart Connection
- ☐ Start Problem Determination Task 21

Fig. 11

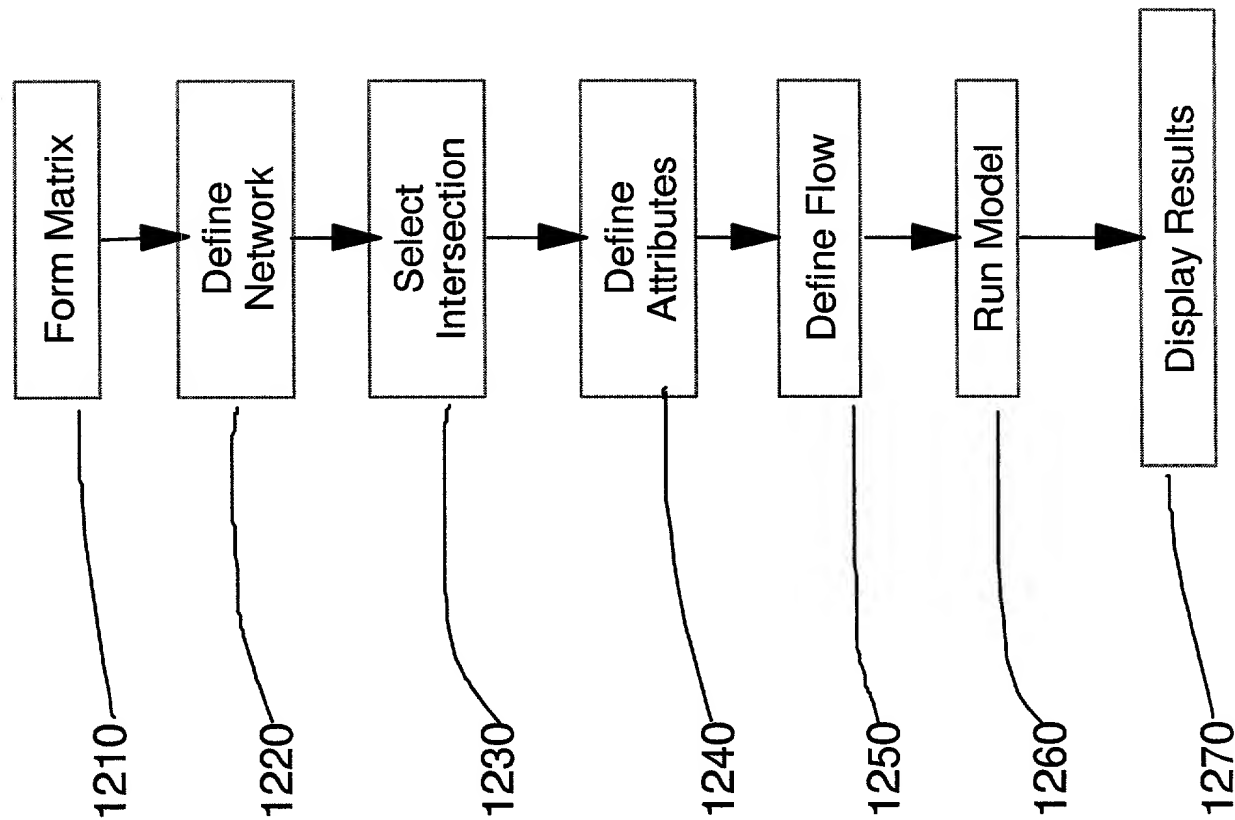


Fig. 12

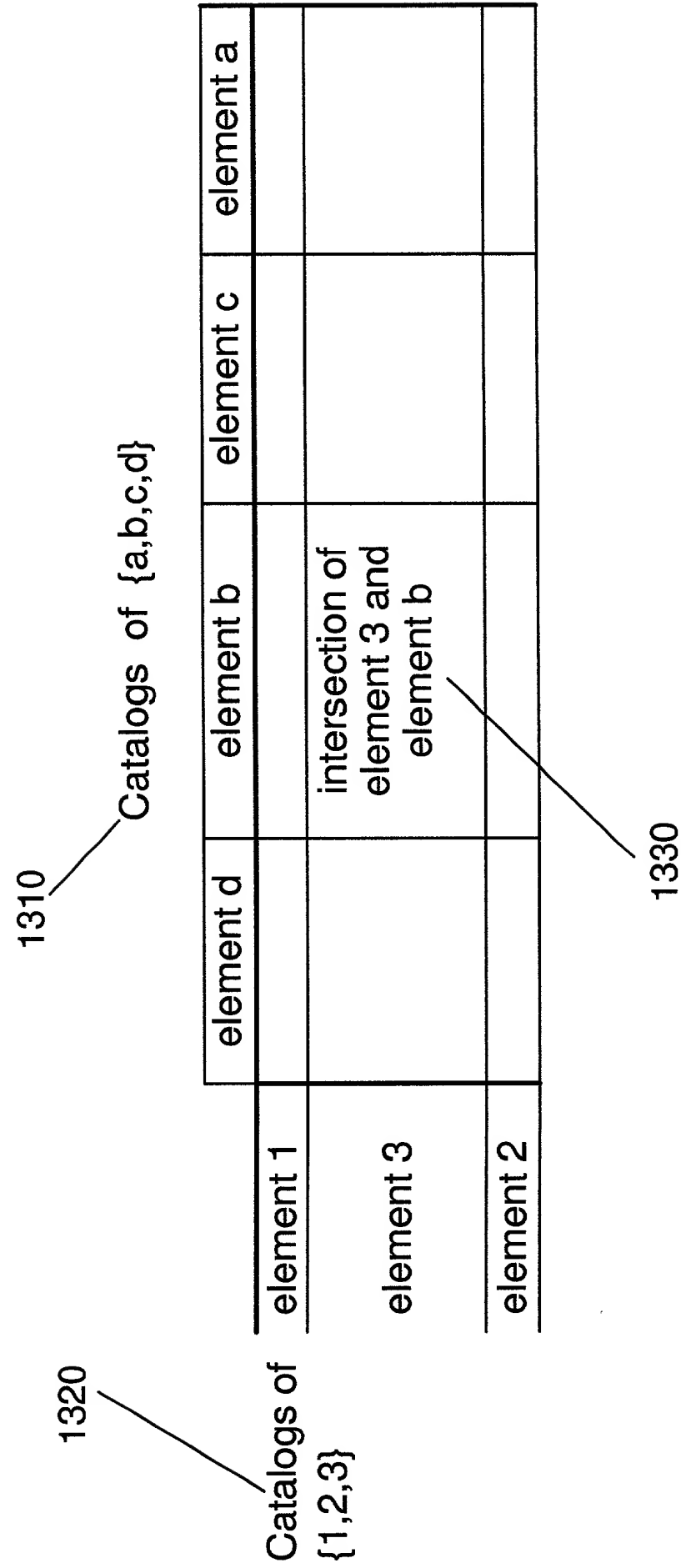


Fig. 13

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

REPRESENTING, CONFIGURING, ADMINISTERING, MONITORING, AND/OR MODELING CONNECTIONS USING CATALOGS AND MATRIXES

the specification of which (check one)

X is attached hereto.

_____ was filed on _____ as United States Application Number

or PCT International Application Number _____

and was amended on _____ (if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, '119(a)-(d) or '365(b) of any foreign application(s) for patent or inventor's certificate, or '365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application, having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)			Priority Claimed	
(Number)	(Country)	(Day/Month/Year Filed)	Yes	No
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

I hereby claim the benefit under 35 U.S.C. '119(e) of any United States provisional application(s) listed below.

(Application Number)	(Filing Date)
_____	_____
(Application Number)	(Filing Date)
_____	_____

I hereby claim the benefit under 35 U.S.C. '120 of any United States Application(s), or '365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States, or PCT International application in the manner provided by the first paragraph of 35 U.S.C. '112, I acknowledge the duty to disclose information material to the patentability of this application as defined in 37 CFR '1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
_____	_____	_____
(Application Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
_____	_____	_____

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith (list name and registration number).

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DATE OF DEPOSIT: JUNE 8, 1999

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